Magnesium alloys offer a base of lightweight engineering materials for electronic, military and transportation applications where weight reduction is crucial for higher efficiency. Understanding fundamental diffusion behavior in Mg alloys elicits better materials properties through the optimization of processing techniques and heat treatments, whose material responses are affected by diffusion. The main objective of this study is to provide a clear, comprehensive description of the diffusion behavior in the technically important magnesium-aluminum binary metallic system.

In this study, diffusion in the Mg-Al system was observed through solid diffusion couples and thin film specimens in the temperature range of 673-573K. The formation and growth of the intermetallic phases, $\beta$-Mg$_2$Al$_3$ and $\gamma$-Mg$_{17}$Al$_{12}$, and the absence of the $\epsilon$-Mg$_{23}$Al$_{30}$ phase was observed. The $\beta$-Mg$_2$Al$_3$ phase grew thicker, had higher parabolic growth constants and lower activation energy for growth. Concentration-dependent interdiffusion coefficients were determined using the Boltzmann-Matano method. Interdiffusion in the $\beta$-Mg$_2$Al$_3$ phase was the highest, followed by the $\gamma$-Mg$_{17}$Al$_{12}$ phase, the Al solid solution and the Mg solid solution. Intrinsic diffusion coefficients at the marker plane composition of 38 at.% Mg in the $\beta$-Mg$_2$Al$_3$ were determined from Heumann’s method for Mg and Al, for which Al was higher. Extrapolations of the impurity diffusion coefficients in both terminal solid solutions were made and compared to available literature data. The thermodynamic factor, tracer diffusivity and atomic mobility of Mg and Al at the marker plane concentration were estimated using Mg activities in the $\beta$-Mg$_2$Al$_3$ available from literature.

The impurity diffusion of Al and self-diffusion of the stable isotope, $^{25}$Mg, in polycrystalline Mg was measured from thin film specimens via depth profiling using secondary ion mass spectrometry. The Al impurity diffusion observed is compared to the extrapolations from the parallel interdiffusion study. The self-diffusion measurements are compared to reported literature values and were observed to be significantly higher. Several reasons for the observed difference in the magnitude of diffusivities are discussed.